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Post-mortem analysis of a 25-cell solid oxide electrolysis stack operated for 9000 hours

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Abstract

A solid oxide electrolysis (SOE) stack has been tested for electrolysis of steam for ~9000 hours and the test results have been previously reported. The stack included 25 planar Ni/YSZ electrode supported cells and Crofer 22 APU interconnects (ICs) with Co-containing protective coatings. The stack, supplied by Topsoe Fuel Cell (TOFC), was based on the now-obsolete "Delta" design of 2014. The stack was operated under a current density of -0.57 and -0.72 A/cm^2, showing a voltage degradation of 2 %/1000 h over the last 6400 h. In this work, detailed post-mortem analysis was performed on this stack in order to detect microstructure changes of solid oxide electrolysis cells (SOECs) and ICs and also to clarify cause of the stack degradation. Half of the stack was embedded into epoxy and was exposed to detailed microstructural characterization from macro- to micrometer scale using different analytical techniques, such as optical microscopy, scanning electron microscopy (SEM), and energy-dispersive X-ray spectroscopy (EDX). Special focus was devoted to Ni re-distribution and loss of Ni percolation in the active Ni/yttria stabilized zirconia (YSZ) electrode, IC oxide scale growth, and IC-cell interface adherence. The characterized microstructural changes were further analyzed in terms of spatial location within the stack, i.e. in relation to the steam/hydrogen flow direction and further correlated with the temperature and current distribution during the 9000 h test period. One critical issue was identified to be loss of Ni from the active Ni/YSZ electrode. A correlation between loss of Ni and fuel flow direction was further established, where the fuel gas inlet being the worst. It was also found that while the fuel side IC-cell contacting remains satisfactory, delamination often occurs between air electrode and IC, leading to performance loss. The various contributions to the entire stack degradation from the detected microstructural changes were also evaluated qualitatively and were correlated with the 2 %/1000 h stack performance decay.